Duet Robust Deep Subspace Clustering

P3D-07

ACMmultimedia Nice, France 21-25 October 2019

Yangbangyan Jiang[1,2], Qianqian Xu[3], Zhiyong Yang[1,2], Xiaochun Cao[1,2], Qingming Huang[2,3,4*]
[1]Institute of Information Engineering, CAS [2]University of Chinese Academy of Sciences
[3]Institute of Computing Technology, CAS [4]BDKM, CAS
{jiangyangbangyan, yangzhiyong, caoxiaochun}@iie.ac.cn, xuqianqian@ict.ac.cn, qmhuang@ucas.ac.cn

Motivation

General form of subspace clustering:

① self-expression ② data reconstruction ③ structure prior

$$\min_{C} \underbrace{\mathcal{L}(Z-ZC)}_{①} + \lambda_1 \sum_i \underbrace{\mathcal{P}(X_i,\hat{X}_i)}_{②} + \lambda_2 \underbrace{\mathcal{R}(C)}_{③}$$

$$s.t.\ \ diag(C)=0$$

When facing corruptions:

- Influence via ①: directly distort the estimated subspace structures

(corruption flow) $Z \xrightarrow{①} C$

- Influence via ②: induce an unfaithful Z, then spread to C

$X \xrightarrow{②} Z \xrightarrow{①} C$

...most existing work only focuses on reduce the influence on ①

Framework

Double-assurance for robustness with two-fold explicit noise modeling:

- Robust reconstruction with $\mathcal{P}(\cdot)$

corruption indicator for each sample

$$\mathcal{P}(X_i,\hat{X}_i) = \frac{1}{2}\|X_i - \hat{X}_i - E_i\|_F^2 + \eta_1\|E_i\|_F$$

F-norm to prevent the loss from being dominated by the corruptions

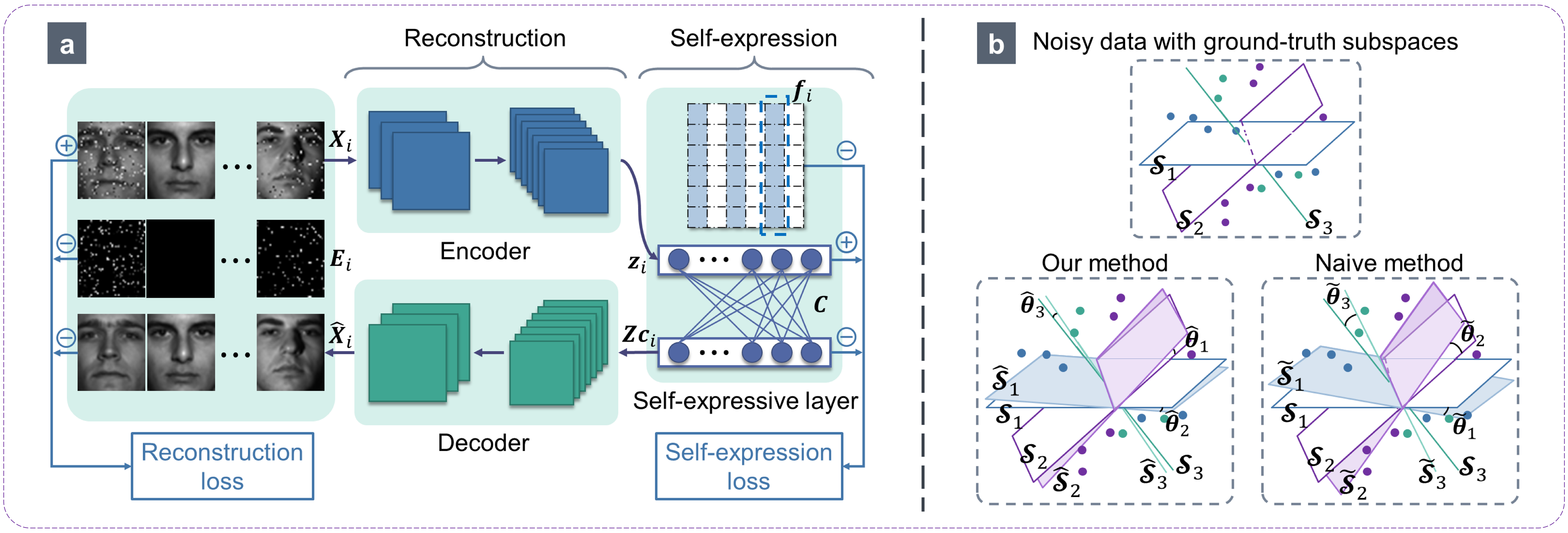
- Robust self-expression with $\mathcal{L}(\cdot)$

$$\mathcal{L}(Z-ZC) = \sum_{i=1}^n \frac{1}{2}\|z_i - Zc_i - f_i\|_2^2 + \eta_2\|f_i\|_2$$

Objective function

$$L = \sum_{i=1}^n \frac{1}{2}\|X_i - \hat{X}_i - E_i\|_F^2 + \eta_1\|E_i\|_F +$$
$$\lambda_1\left(\frac{1}{2}\|z_i - Zc_i - f_i\|_2^2 + \eta_2\|f_i\|_2\right) + \lambda_2\|C\|_p$$

non-smooth! (non-differentiable at zero)



Smoothing of norms

Definition 2 ($\frac{1}{\mu}$-smooth approximation, [2]). *For a convex function $h:\mathbb{E}\to\mathbb{R}$, a convex differentiable function $h_\mu:\mathbb{E}\to\mathbb{R}$ is said to be its* $\frac{1}{\mu}$***-smooth approximation*** *with parameters (α,β) if for any $\mu>0$ the following holds:*

1) $h_\mu(x) \le h(x) \le h_\mu(x) + \beta\mu$ *for all* $x\in\mathbb{E}$,
2) h_μ *is* $\frac{\alpha}{\mu}$*-smooth.*

$\frac{1}{\mu}$-smooth approximation of F-norm and ℓ_2-norm:

$$\|X\|_{F_{(\mu)}} = \sqrt{\|X\|_F^2+\mu^2} - \mu$$

$$\|x\|_{2_{(\mu)}} = \sqrt{\|x\|_2^2+\mu^2} - \mu$$

balance the approximation accuracy and smoothness

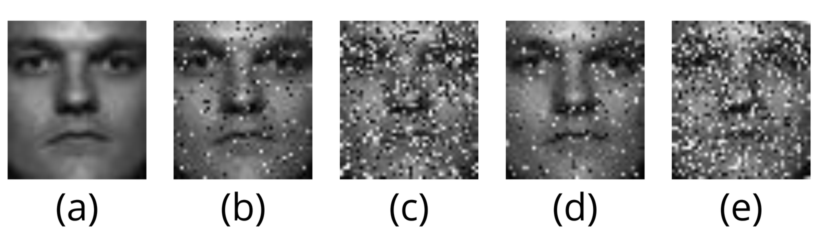
Smoothed objective function:

$$L = \sum_{i=1}^n \frac{1}{2}\|X_i - \hat{X}_i - E_i\|_F^2 + \eta_1\|E_i\|_{F_{(\mu)}} +$$
$$\lambda_1\left(\frac{1}{2}\|z_i - Zc_i - f_i\|_2^2 + \eta_2\|f_i\|_{2_{(\mu)}}\right) + \lambda_2\|C\|_p$$

a totally differentiable network, simultaneously update all the params

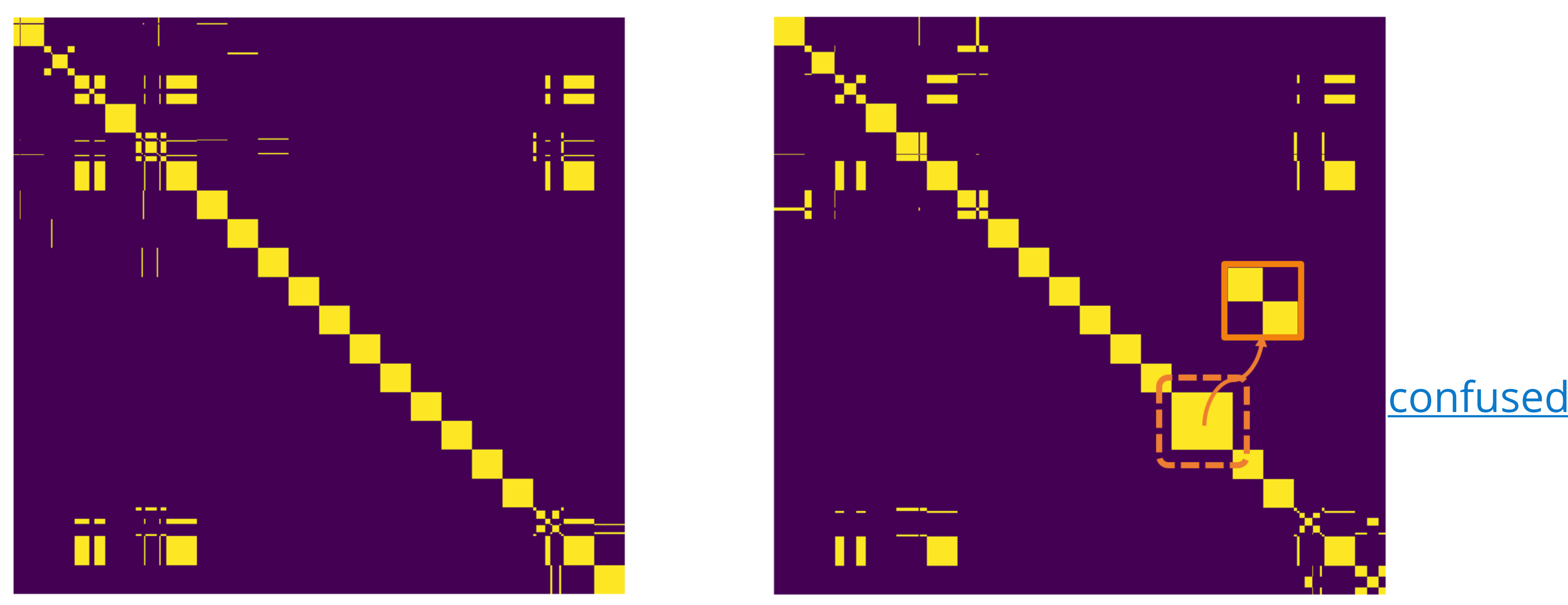
auto-encoder | self-express coef. C | corruption terms E_i, f_i

Experiments



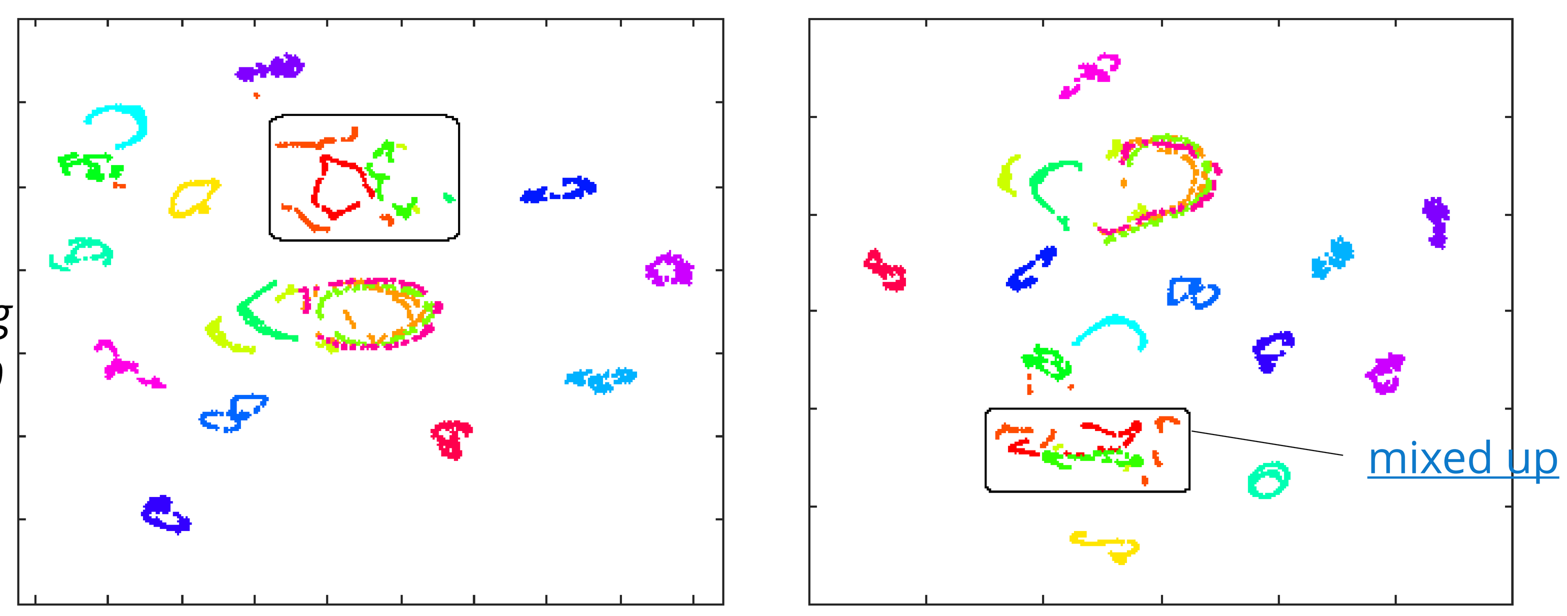
Corrupted samples on Extended Yale B dataset. (a) Original image, (b/c) 10%/40% corrupted by random pixel corruption, (d/e) 10%/40% corrupted by Gaussian noise.

Indicator matrix on COIL20



ours DSC-Net (NIPS17)

Spectral embedding on COIL20



ours DeepCogSC (MM18)